

DIESEL ENGINE POWER PLANT DESIGN

Section I. DIESEL ENGINE-GENERATORS

7-1. Engines

a. Diesel engines have higher thermal efficiencies than other commercial prime movers of comparable size. Diesel engine-generators are applicable to electric loads, from about 10 to 5000 kilowatts. Diesel-engine-driven electric generator sets are divided into three general categories based on application as follows:

(1) *Class A:* Diesel-electric generator sets for stationary power plants generating prime power continuously at full nameplate kW rating as the sole source of electric power.

(2) *Class B:* Diesel-electric generators sets for stationary power plants generating power on a standby basis for extended periods of time where months of continuous operation at full nameplate kW rating are anticipated.

(3) *Class C:* Diesel-electric generator sets for stationary power plants generating power on an emergency basis for short periods of time at full nameplate kW rating where days of continuous operation are anticipated.

b. Diesel engines normally will be supplied as skid mounted packaged systems. For multiple-unit procurement, matched engine-generator sets will be provided for units of 2500kW electrical output or less. For larger units, investigate the overall economics and practicality of purchasing the generators separately, recognizing that the capability for reliable operation and performance of the units are sacrificed if engine and generator are bought from two sources.

c. Engines and engine-generator sets are normally provided with the primary subsystems necessary for engine operation, such as:

- (1) Starting system.
- (2) Fuel supply and injection system.
- (3) Lubrication system and oil cooling.
- (4) Primary (engine) cooling system.
- (5) Speed control (governor) system.
- (6) Required instrumentation.

d. The designer must provide for the following

- (1) Intake air.

(2) Exhaust and exhaust silencing.

(3) Source of secondary cooling (heat sink).

(4) Engine foundation and vibration isolation.

(5) Fuel storage, transfer and supply to the engine.

(6) Electrical switchgear, stepup transformer, if required, and connection to distribution wiring.

(7) Facilities for engine maintenance, such as cranes, hoists and disassembly space.

(8) Compressed air system for starting, if required.

e. Generator design criteria are provided in Chapter 4.

7-2. Fuel selection

A fuel selection is normally made according to availability and economic criteria during the conceptual design. Fuels are specified according to ASTM, Federal and military specifications and include:

a. ASTM Grades 1-D, 2-D, and 4-D as specified by ASTM D 975. These fuels are similar to No. 1, No. 2 and No. 4 heating oils.

b. Federal Specification Grades DF-A and DF-2 (see Federal Specification VV-F-800). These specifications parallel ASTM Grades 1-D and 2-D, respectively.

c. Jet Fuel Grade JP-5 (Military Specification MIL-T-5624).

d. Marine Diesel (Military Specification MIL-F-16884). Marine Diesel is close to ASTM No. 2-D, although requirements differ somewhat.

e. ASTM No. 6, or its Federal equivalent, or Navy special may be specified for engines in excess of 2000 kW if economics permit. Fuel selection must be closely coordinated with the requirements of the engine manufacturer. The No. 2-D or DF-2 fuels are most common. If fuel is stored at ambient temperatures below 20°F., No. 1-D or DF-A (arctic fuel) should be considered. ASTM No. 4-D or No. 6 are residual oil blends which require preheating prior to burning. Fuel oil storage and handling equipment and the engine itself will be specifically designed for burning these viscous fuel oils.

Section II. BALANCE OF PLANT SYSTEMS

7-3. General

Balance of plant systems are those which must be provided and interfaced with a packaged diesel or diesel-generator set to provide an operational generating unit.

7-4. Cooling systems

a. Water-to-water systems. Jacket water and lube oil cooling heat exchangers are cooled by a secondary circulating water system. Normally, a recirculating system will be used. Heat is dissipated to the atmosphere through an evaporative, mechanical-draft cooling tower. If the plant is located on or near a body of water, once-through circulating water will be evaluated. Bidders will be informed of the type and source of secondary water used so heat exchangers can be designed for their intended service.

b. Water-to-air systems. Water-to-air systems will be restricted to small engines. If an integral (skid mounted) radiator is used, sufficient cooling air will be provided. Outside air may be ducted to the radiator air inlet. Ductwork will be designed for minimum pressure loss. The cooling fan(s) will be checked for adequate flow (cfm) and static pressure under the intended service. Air leaving the radiator normally goes to the engine room and is exhausted. Cooling air inlets will be equipped with automatic dampers and bird screens.

7-5. Combustion air intake and exhaust systems

a. Purpose. The functions of the intake and exhaust systems are to deliver clean combustion air to the engine and dispose of the exhaust quietly with the minimum loss of performance.

b. Intake. The air intake system usually consists of air intake duct or pipe appropriately supported, a silencer, an air cleaner, and flexible connections as required. This arrangement permits location of area of air intake beyond the immediate vicinity of the engine, provides for the reduction of noise from intake air flow, and protects vital engine parts against airborne impurities. The air intake will be designed to be short and direct and economically sized for minimum friction loss. The air filter will be designed for the expected dust loading, simple maintenance, and low pressure drop. Oil bath or dry filter element air cleaners will be provided. The air filter and silencer may be combined.

c. Exhaust. The exhaust system consists of a muffler and connecting piping to the atmosphere with suitable expansion joints, insulation, and supports. In cogeneration plants, it also provides for utilization of exhaust heat energy by incorporating

a waste heat boiler which can be used for space heating, absorption refrigeration, or other useful purpose. This boiler produces steam in parallel with the vapor phase cooling system. The exhaust silencer attenuates exhaust gas pulsations (noise), arrests sparks, and in some cases recovers waste heat. The muffler design will provide the required sound attenuation with minimum pressure loss.

7-6. Fuel storage and handling

a. Storage requirements.

(1) Aboveground fuel storage tanks with a minimum capacity for 30 days continuous operation will be provided for continuous and standby duty plants. Fuel storage shall be designed to the requirements of NFPA 30. A tank with 3 day storage capacity will be provided for emergency duty plants.

(2) For continuous duty plants, provide a day tank for each engine. The tank will provide a 4-hour storage capacity at maximum load. The tank will be filled by automatic level controls and transfer pumps. Standby plants will be provided with day tanks of sufficient capacity to permit manual filling once per shift (10-hour capacity). No separate day tank is required for emergency plants.

b. Fuel handling. Provide unloading pumps if fuel is to be delivered by rail car or barge. Most fuel tank trucks are equipped with pumps. Provide transfer pumps capable of filling the day tank in less than 1/2 hour when the engine is operating at maximum load. Duplex pumps, valved so that one can operate while the other is on standby, will be provided for reliability. Pipeline strainers and filters will be provided to protect the fuel pumps and engine injectors from dirt. Strainers and filters will not pass particles larger than half the injector nozzle opening.

7-7. Engine room ventilation

About 8 percent of the heating value of the fuel consumed by the engine is radiated to the surrounding air. It is essential that provision be made for removal of this heat. Engine room temperature rise should be limited to 15°F. For engines with wall mounted or ducted radiators, radiator fans may be sufficient if adequate exhaust or air relief is provided. If engines are equipped with water cooled heat exchangers, a separate ventilation system will be provided. The approximate ventilation rate may be determined by the following formula:

$$C F M = \frac{1,000 \times HP}{T}$$

where:

HP = maximum engine horsepower

T = allowable temperature rise, °F.

Provision will be made to allow for reducing the air flow during the cooler months so as not to over-cool

the engine room; however, jacket water cooling will remain within recommended limits at all times.

Section III. FOUNDATIONS AND BUILDING

7-8. General

Chapter 2 should be consulted for the civil facilities design criteria associated with a diesel power plant. This section amplifies the civil engineering aspects directly applicable to the diesel plant.

7-9. Engine foundation

a. Design considerations.

(1) The foundation will have the required mass and base area, assuming installation on firm soil and the use of high quality concrete. Before final details of the foundation design are established by the designer, the bearing capacity and suitability of the soil on which the foundation will rest will be determined. Modification of the manufacturer's recommended foundation may be required to meet special requirements of local conditions. Modifications required may include:

(a) Adjustment of the mass.

(b) Additional reinforcing steel.

(c) Use of a reinforced mat under the regular foundation.

(d) Support of the foundation on piles. Piling may require bracing against horizontal displacement.

(2) The engine foundation will extend below the footings of the building and the foundation will be completely isolated from the walls and floors of the building. The foundation block will be cast in a single, continuous pour. If a base mat is used, it will be cast in a separate continuous pour and be provided with vertical re-bars extending up into the foundation block.

b. Vibration mounts.

(1) For small engine installations where there is a possibility of transmission of vibration to adjacent areas, the engine foundations will be adequately insulated by gravel, or the engine mounted on vibration insulating material or devices. Vibration mounts for larger engines become impractical and foundation mass must be provided accordingly.

(2) Skid mounted generating units will be supplied with skids of sufficient strength and rigidity to maintain proper alignment between the engine and the generator. Vibration isolators, either of the adjustable spring or rubber pad type, will be placed between the unit skid and the foundation block to minimize the transmission of vibrations.

7-10. Building

a. Location.

(1) A diesel engine power plant has few limitations regarding location. Aesthetically, an architecturally attractive building can enclose the equipment if required. Fuel can be stored underground if appearance so dictates. Proper exhaust and intake air silencing can eliminate all objectionable noise. Air and water pollution problems are minimal with most recommended fuels.

(2) Consider the relative importance of the following when selecting a plant site:

(a) Proximity to the center of power demand.

(b) Economical delivery of fuel.

(c) Cost of property.

(d) Suitability of soil for building and machinery foundations.

(e) Space available for future expansion.

(f) Proximity to potential users of engine waste heat.

(g) Availability of water supply for cooling systems.

b. Arrangement.

(1) In designing the power plant building, a general arrangement or plant layout will be designed for the major components. The arrangement will facilitate installation, maintenance and future plant expansion. Ample space shall be provided around each unit to create an attractive overall appearance and simplify maintenance for engines and auxiliary equipment.

(2) In addition to the basic equipment arrangement, provide for the location of the following, as required by the project scope:

(a) Office space.

(b) Lunchroom and toilet facilities.

(c) Engine panels, plant and distribution switchgear, and a central control board (Chapter 5, Section I).

(d) Cooling system including pumps and heat exchangers.

(e) Lube oil filters and, for heavier fuels, fuel oil processing equipment such as centrifuges.

(f) Tools and operating supplies storage.

(g) Facilities for maintenance.

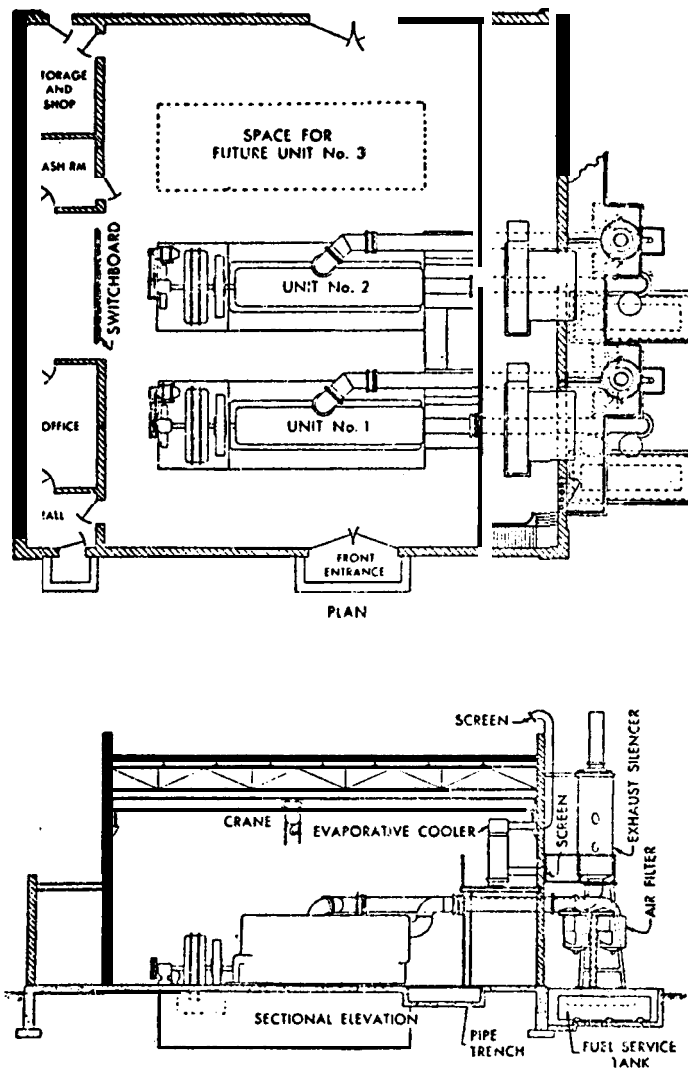
(h) Heat recovery equipment, if included.

(3) The main units should usually be lined up in parallel, perpendicular to the long axis of the engine room thus making unlimited future expansion easy

and economical. The engine bay will be high enough for a motorized, overhead traveling crane. The crane, if economically feasible, will be sized for maintenance only. The switchgear will be located at the generator end of each unit, permitting the shortest

possible wiring between the switchgear and generators. The switchgear may be enclosed in a separate room or maybe a part of the main engine bay.

(4) A typical small two-unit diesel power plant arrangement is shown in Figure 7-1.



U.S. Army Corps of Engineers

Figure 7-1. Typical diesel generator power plant.